Current Status of the Development and Application of Mesoscale and Global WRF/Chem at NCSU

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Weather Research and Forecast/Chemistry Model (WRF/Chem) at NCSU: Overview

- **Key Collaborators**
  - G. Grell, S. Peckham, and S. McKeen, NOAA-ESRL
  - J. Fast, W. Gustafson Jr., R. Easter, R. Zaveri, and S. Ghan, PNNL
  - K. Schere, T. Otte, J. Pleim, G. Sarwar, J. Herwehe, and S.T. Rao, U.S. EPA/NOAA-ASMD, C. Jang, EPA/OAQPS
  - W. Skamarock, NCAR-MMMD; L. Emmons and F. Vitt, NCAR-ACD
- **History and Milestones**
  - Jan., 2004: Code installed and operational at NCSU
  - 2004: Incorporation of MADRID into WRF/Chem
  - 2005: Testing, application, evaluation over TeXAQS2000 (WRF 2005, AGU 2005)
  - 2006: Incorporation of CB05 and evaluation (AMS, 2006, WRF 2006, CMAS 2006)
  - 2007-present:
    - Application at 36-km over CONUS (WRF 2007, CMAS 2007, AMS 2008)
    - Testing of WRF/Chem-MADRID at 24-km over New England (CMAS 2007)
    - Implementation of CB05-KPP in WRF/Chem-MADRID (AMS 2008)
    - Development and Testing of Global WRF/Chem (AMS 2008)

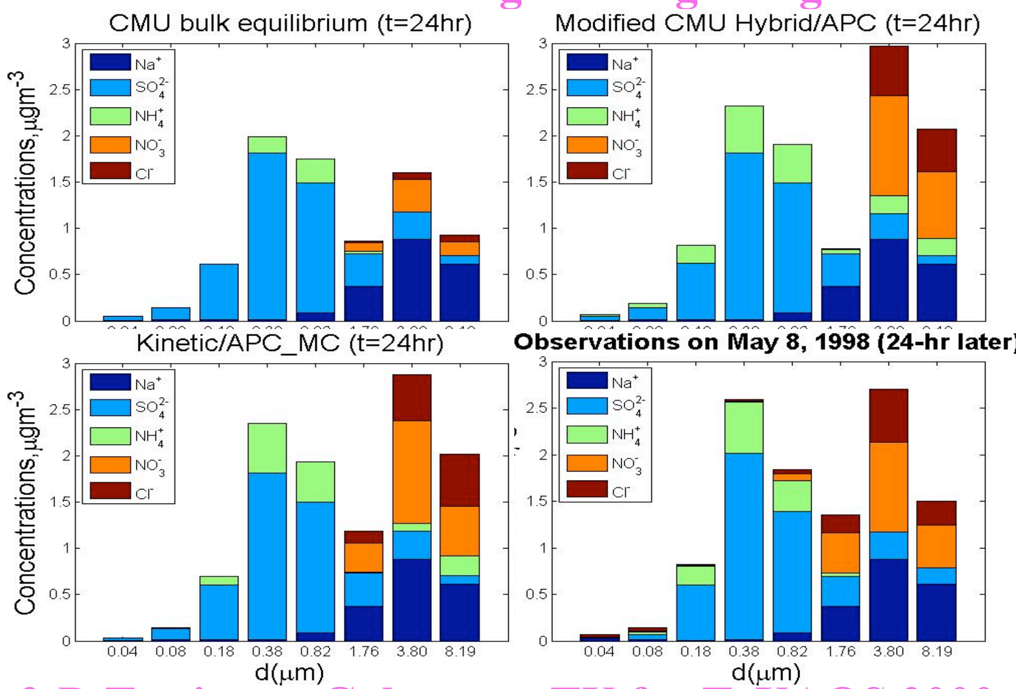
Gas and Aerosol Treatments in WRF/Chem

	MADE/SORGAM	MOSAIC	MADRID
Gas chemistry	RADM2/RACM	CBM-Z	CBM-Z/CB05
Size structure	Modal (3 modes)	Sectional (8 bins)	Sectional (8 bins)
Inorganic species	NH_4^+, $SO_4^=$, NO_3^-, H_2O	plus Na^+, Cl^-	plus Na^+, Cl^-
Equilibrium	MARS-A	MESA-MTEM	ISORROPIA
Coagulation	Modal	Sectional	Sectional
Nucleation	Binary	Binary	Binary
Condensation	Modal	Sectional	Sectional
Gas/Particle Mass transfer	Full equilibrium	Dynamic with ASTEEM	1. Full equilibrium 2. Dynamic 3. Hybrid
SOA formation	Reversible absorption (8 classes VOCs)	Same as MADE/SORGAM	MADRID 1: Reversible absorp. (39 VOCs) MADRID 2: Reversible absorp. and dissolution (42 VOCs)
Dry deposition	Resistance transfer with a simple parameterization for V_d	Resistance transfer	Resistance transfer

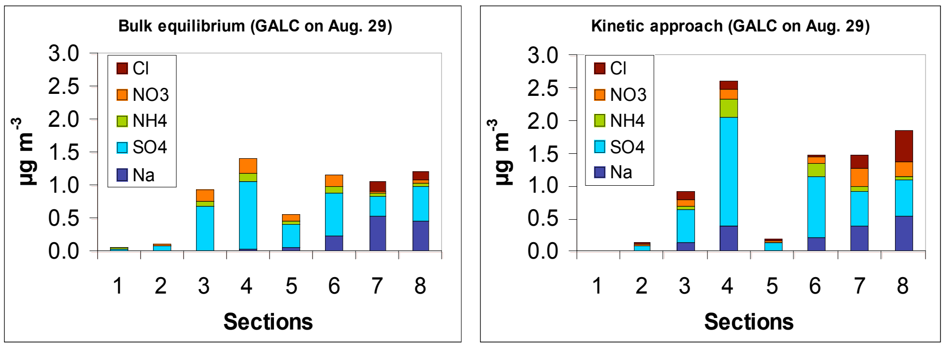
Development Highlights:
Incorporation of MADRID into WRF/Chem

- **Gas/Particle Mass Transfer**
  - Bulk equilibrium
  - Hybrid
  - Kinetic
- **Objectives**
  - Identify limitations/advantages
  - Develop a computationally-efficient module
- **Approaches**
  - Box model development
  - Evaluation using size-resolved observations
  - 3-D model testing
- **3-D Testbeds**
  - TeXAQS 2000 (12-km)
  - New England 2004 (27-km)
  - CONUS 2001 (36-km)
- **Major Findings**
  - Bulk equilibrium approach fails to predict semi-volatile species in areas with active coarse PM, where kinetic approach is needed
  - Kinetic and hybrid approaches take 1.8-3.6 and 1.05 times more CPU than bulk equilibrium
  - Gases and size-resolved PM measurements are needed (e.g., ASP)

Box MADRID Testing at Hong Kong Site

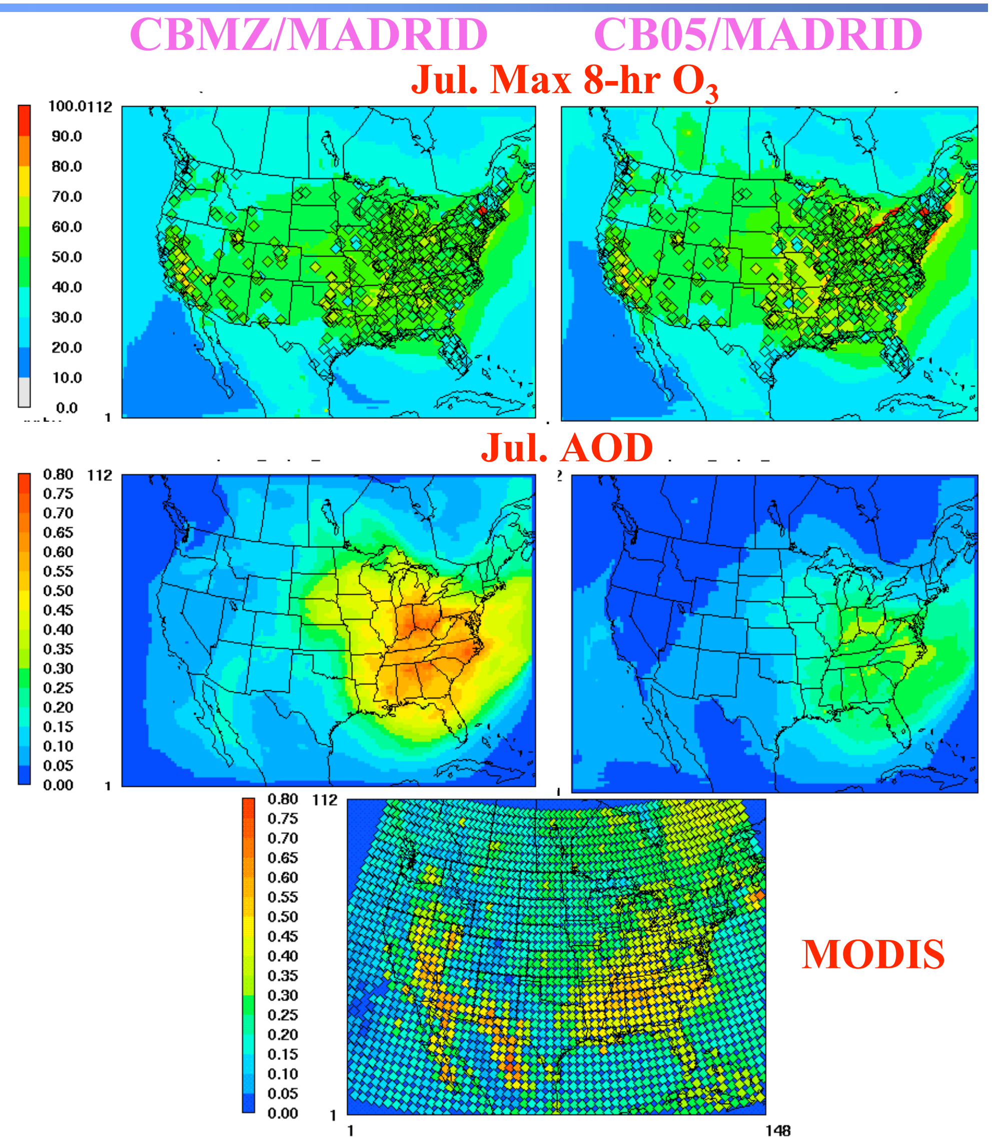


3-D Testing at Galveston, TX for TeXAQS 2000



Development Highlights: Implementation of CB05_KPP in WRF/Chem-MADRID

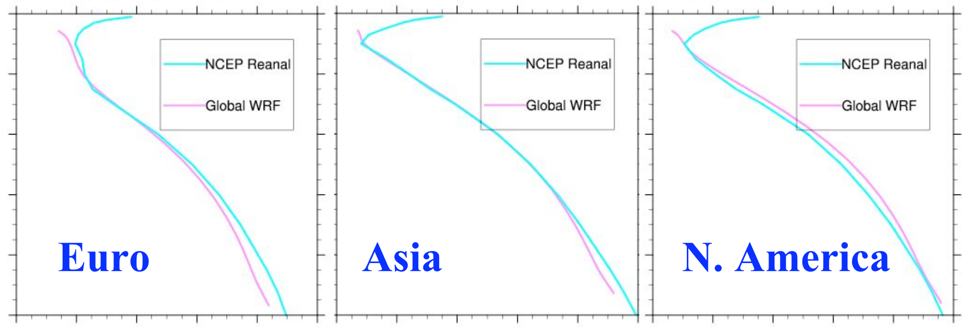
- Gas-Aerosol Coupling
  - CBMZ-MADRID
  - CB05-MADRID
  - SAPRC99-MADRID
- Objectives
  - Examine sensitivity of aerosol predictions to gas chemistry
  - Improve SOA treatment
- Approaches
  - Implementation of CB05_KPP
  - Intercomparison with CBMZ/MADRID
  - Evaluation using observations
- 3-D Testbeds
  - Jul. 2001 CONUS (36-km)
  - Jul./Jan. 2005 Asia (36-km)
- Major Findings
  - WRF/Chem shows reasonably-good skills for surface O_3/$PM_{2.5}$, column NO_2 and CO, but relatively poor performance for TOR in Jul. and AOD in Jan.
  - CB05 gives higher O_3, CO, and HCHO; lower NO_x, HNO_3, $PM_{2.5}$, and its inorganic components



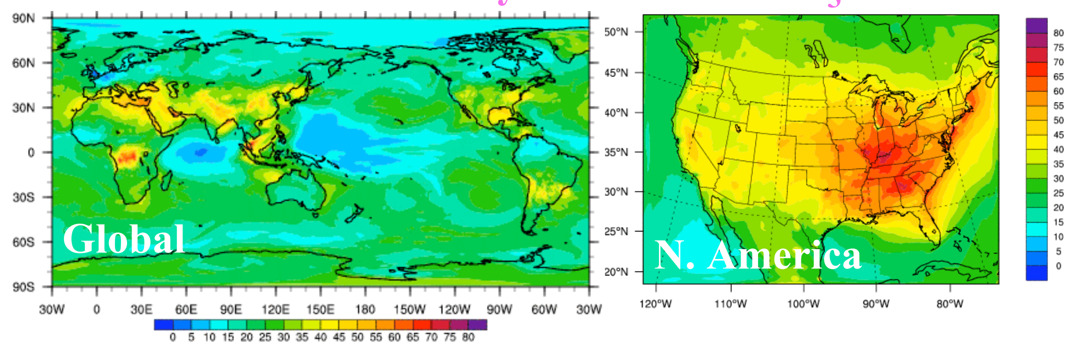
Development Highlights: Global-through-Urban WRF/Chem (GU_WRF/Chem)

- **Key Development**
  - Extension of CB05
  - Addition of Hg chemistry
  - Improvement of aerosol treatments
  - Addition of plume-in-grid treatments
- **Objectives**
  - Develop a unified model framework for multiscale modeling
  - Apply it to replicate and examine climate-chemistry-aerosol-cloud feedbacks
- **Approaches**
  - Couple chemistry with global WRF
  - Expand chemistry to represent globe
  - Evaluation using observations
- **3-D Testbeds**
  - Jan., Jul., Aug. 2001 (1.125°× 1.125°)
  - Jan./Jul. 2001 (4°× 5°)
- **Major Findings**
  - G-WRF/Chem demonstrates some skills
  - Goddard shortwave scheme outperforms Dudhia scheme
  - Reinitialization is needed
  - Upper BCs need to be improved

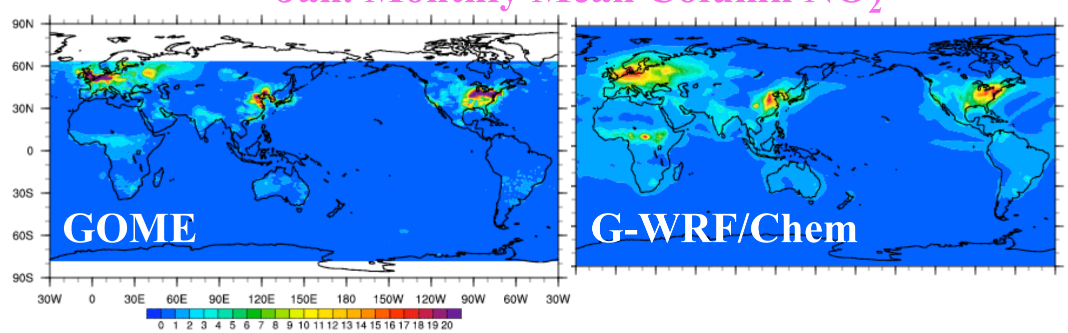
Vertical T Profile over Northern Hemisphere



Jul. Monthly Mean Surface O_3



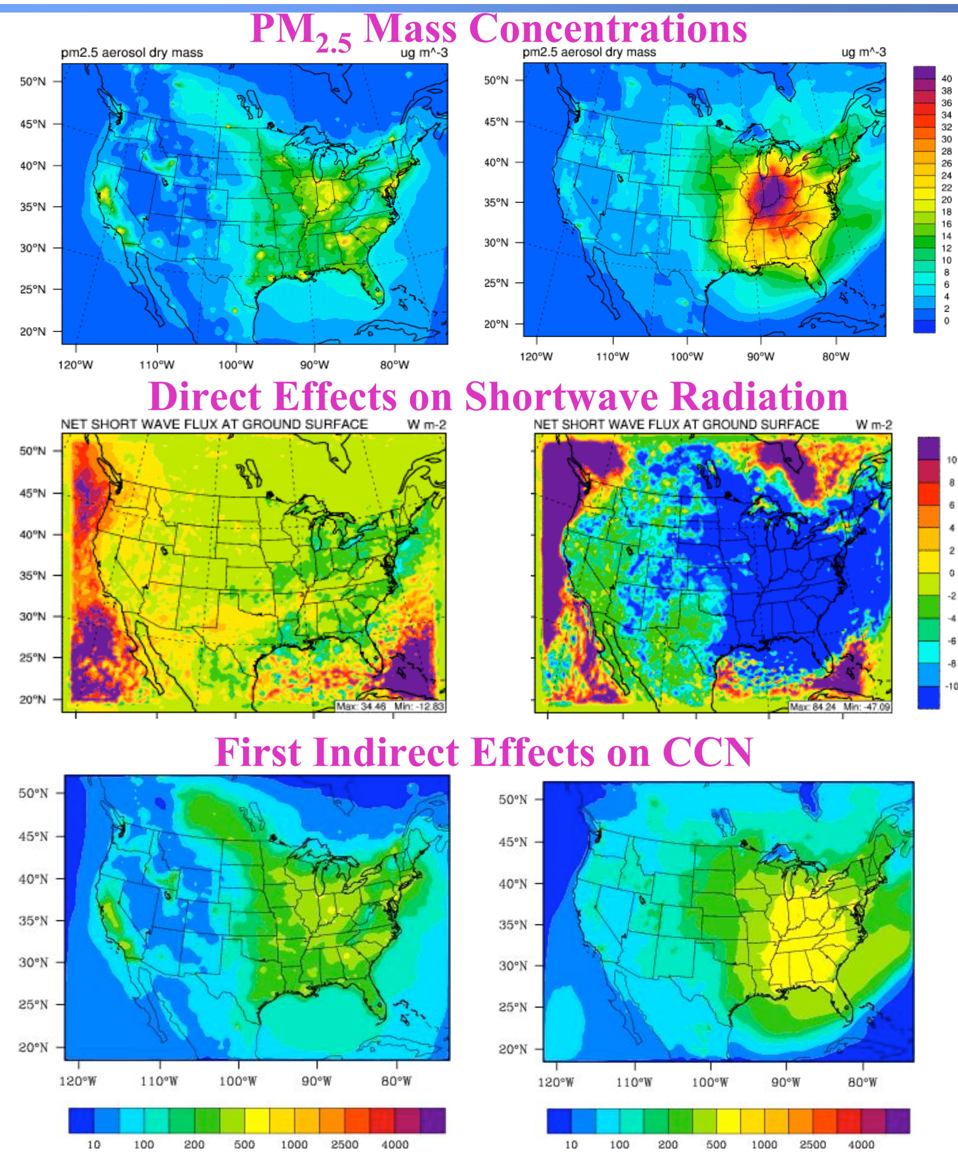
Jan. Monthly Mean Column NO_2



Application Highlights: Aerosol-Radiation-Cloud Feedbacks with WRF/Chem-MOSAIC

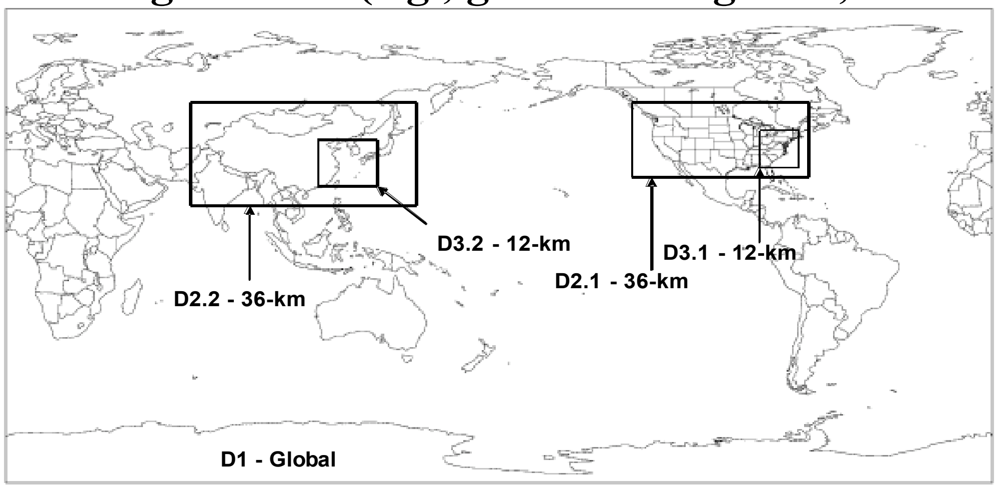
Jan. **Jul.**

- **Objectives**
  - Test model configurations
  - Examine aerosol-radiation-cloud feedbacks
  - Assess impact of climate change on AQ
- **Approaches**
  - Met; Met+Gas; Met+Gas+PM+Cloud
  - Seasonal contrast (Jan. vs. Jul.)
  - Evaluation using observations
- **3-D Applications**
  - TeXAQS 2000 (12-km)
  - Jan./Jul. 2001 CONUS (36-km)
  - Jan./Jul. 2005 Asia (36-km)
- **Preliminary Findings**
  - PM can decrease shortwave radiation, T, and PBLH; increase CCN, and affect JNO_2, SH, WSP, and precip. in different ways
  - Overall stronger feedbacks in Jul. than Jan., and over EUS than WUS
  - Data are needed to verify simulated feedbacks (e.g., ASP)



Planned Model Development and Applications

- **Meso- and Global-WRF/Chem**
  - **Emissions:** global, online emission module for dust, plume-in-grid
  - **Gas-phase and PM chemistry:** CB05, SAPRC99, stratospheric, chlorine, Hg
  - **Aerosol treatments:** nucleation, coagulation, SOA, aerosol activation
- **Applications (DOE CCPP/ASP)**
  - **Current-year:** CAM4/MIRAGE (2001-2005) and GU-WRF/Chem (2001)
  - **Future-year:** CAM4/MIRAGE (2050-2054) and GU-WRF/Chem (2050)
  - **Sensitivity:**
    - model inputs (e.g., BVOC emissions from land/ocean)
    - model formulations (e.g., SOA, new PM formation, aerosol-cloud inter.)
    - model configurations (e.g., global vs. regional, fine vs. coarse resolutions)



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